EFFECT OF CLAY UPPER SAND SOILS ON SKIRTED FOOTING DUE TO VERTICAL LOADING

PUBLIKASI ILMIAH

Prepared as one of the requirement for achieving Bachelor Degree (Strata I) of Civil Engineering

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UNIVERSITAS MUHAMMADIYAH SURAKARTA

2017

APPROVAL SHEET

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SCIENTIFIC PUBLICATION

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ABSTRACT

The foundation is element of the building structure which connects the structure to the ground, and transfers loads from the structure to the ground. Skirts are used to improve the bearing capacity of shallow footings on clay upper sand soil by constraining the soil beneath and containing the plastic flow of soil. They are used as an alternative to deep foundations in soils with low strength at the surface, the bearing capacity formulation is used in the analysis of failure. The research are performing nine laboratory experiments on circular steel footings of different diameters footing made of steel diameter 75 mm, 100 mm and 150 mm with length of skirt 100 mm and 150 mm on clay upper sand by keeping the similar water content and compaction method, the research compared between clay upper sand and sand upper clay. From the result show the value of bearing capacity of clay upper sand greater then sand upper clay. The results from the laboratory show that the skirt is effectively to reduce the foundation settlement on clay which is observed on similar load 1 kN. The observations on L/D ratio on similar diameter show that the higher L/D ratio the smaller settlement. The load generally increase, when it is observed on settlement 3 mm with similar diameter, it shows that when increase the length of skirt increase the load value on the footing. This research include also comparing between the effect of skirted footing on clay upper sand and sand upper clay it is observed in same diameter footing and length of skirt smaller settlement and higher of loading for clay upper sand .

Keywords: ***bearing capacity, circular footing, foundation, settlement, skirt.***

1. INTRODUCTION

The bearing capacity of soil is defined as the capacity of the soil to bear the loads coming from the foundation. The bearing capacity of soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil. Ultimate bearing capacity is the theoretical maximum pressure which can be supported without failure, allowable bearing capacity is the ultimate bearing capacity divided by a factor of safety. The bearing capacity of the soil below the foundation is the most important factor for designing the foundation .

The bearing capacity formulation is used to analyses the failure of skirted footings tested under pure vertical load. It was found that bearing capacity increases with the length of the footing skirt. Axial symmetric bearing capacity factors for flat footings were used. The depth effect did not affect significantly the surcharge bearing capacity factor for caisson aspect ratios. In this research, the foundation improvement should be conducted as the alternative solution by adding the structural skirt to the foundation or called "skirted foundation". Skirted foundation is steel foundation with a thin circumferential skirt steel around the periphery of foundation.

(Ashraf & Wasim, 2011), investigated the behavior of combination of skirt circular footing resting on layered soil laboratory model tests for studying the improvement of soft clay layer by using both partially replaced sand piles with/without confinement. This research is performed to study the effect of sand pile to improve the bearing capacity and to control the settlement. Also the research aimed at investigating the variation of subgrade modulus, and the induced failure mechanism of shallow circular footing on replaced soil with/without skirts. (Aghabari and Mohamedzein, 2006) presented the results of an experimental study on the behavior of circular foundations with a structural skirt resting on sand. The structural skirts were fixed to perimeter of the foundations and can be used to new or existing shallow foundations.

2. METODE

The purpose from this research is for determining the relationship between the settlement of clay upper sand and the load on the circular footing with/without skirted. The research is conducted by comparing the six skirted circular footing models with the three unskirted circular footing model. There will be nine laboratory experiments. The layered soil will be kept on the same formation in every experiments. To study the behavior of skirted footing on clay, the laboratory test conducted on small scale model. The equipments used are six skirted Circular Footing Models. The circular footing having a diameter (D) of 7,5 cm, 10 cm, 15 cm external diameter, with a thickness of footing is 10 mm and skirt length (L) equal to 10 cm, 15 cm and have thickness 2 mm for each diameter. Then, the ratio of skirt length (L) to the footing diameter (D), L/D are 1.33 (100/75), 1.00 (100/100), 0.67 (150/100), 2.00 (150/75), 1.50 (150/100), 1.00 (150/150).

All footing models are made from steel plates. Skirts are welded firmly and accurately attached to the periphery of footings. Every model footings have a notch at the center of the top face for mounting the piston. Three unskirted circular footing models, with 75, 100, 150 mm diameter and 10 mm thickness. L/D is 0.00.

Figure 1 Skirted and Unskirted Circular Footing Model

Bin. It made of single steel cylinder of 500 mm height and 600 mm diameter, with the top side circle is opened. Hydraulic Loading Machine. Frame Load Testing Machine has maximum load 250 kN , the value of loading shown on the digital device and two-dial gauges that attached vertically on the top surface of the footing to know the displacement occurred. The piston used long and conical at the ends, is placed right above the notch of footing.

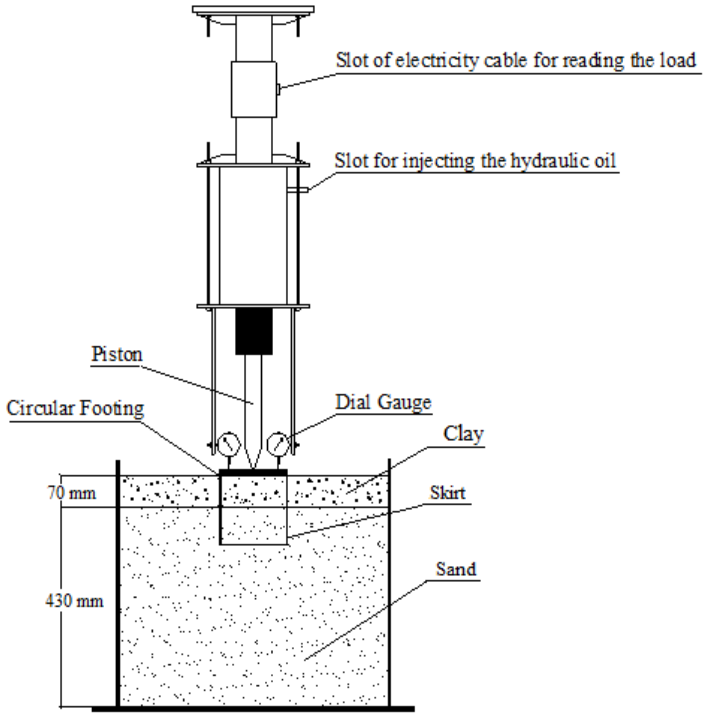

Figure 2 Sketch Setup of Testing Procedures

Some steps conducted for this research that will described as follow:

1. Step I

   Preparing and setting up the equipments and the material of clay and sand that used For the experiment. Clay and sand should be taken from the same condition and location. The soil is dried on the room temperature (27-30o C) before using for investigation of water content, to have the value of water content.

2. Step II

   Clay and sand that has been dried (at room temperature), and then investigated the value of water content..

3. Step III

   Time for conducting the laboratory test of the effect of skirted footing toward the settlement of soil layered.

   A. The value of initial water content of clay and sand is used to determine the add of water quantity.
   B. Mix the water with clay and water with sand, Then, compact the sand for 8 layers and the clay for 2 layers in the bin and blow 100 blows for each layer.
   C. Set the bin of clay and sand that has been compacted on hydraulic loading machine.
   D. For the first test, placing the skirt footing that has L/D = 0.5 right on middle of soil bin, and push it until all the skirt is already inside soil layered, observe the top surface of clay inside the skirt via two open holes on the footing.
   E. Exactly set the two dial gauges on the left and right side of footing, and this dials touch the top surface of footing. This two dials is useful for observing the settlement. So, set the piston right in the central of footing and also having contact with the notch of footing.
   F. Skirted circular footing is already on the right position, running the hydraulic loading machine, observing and recording all of the changes that occurred on every dial and on the digital device of loading. The value of settlement will be shown by the two dial gauges that in touch with footing. And the value of loading that cause the settlement will be shown by the digital device of hydraulic loading machine. Last, stopping the loading when the loading decreases, as the indication that the foundation has been failure. The next laboratory test, conducting the same test sequence above, but it just replace the skirted circular footing.

4. Step IV

   To comparison data between the skirted footing and the unskirted footing, Need to conducted the laboratory test on the footing without the skirt. The step has the same sequence with the Step III, but it just replaces the skirted footing with the unskirted footing, diameter 75, 100, and 150 mm.

5. Step V

   The final step is analyzing all the data and concluding the accomplished laboratory tests.

3. RESULT AND DISCUSSION

The investigation of "Effect of clay upper sand soils on skirt footing due to vertical loading" was conducted of circular footing model resting on clay upper sand, six skirted footing the diameter of footing (D) 75 mm, 100 mm,150 mm with length (L) 100 mm and 150 mm, and three unskirted circular footing with the diameter 75 mm, 100 mm, 150 mm. This experiment has been conducted with similar value of water content and method of compaction. The water content test was investigated around 20% for layered soils as the reference for all testing model and that value was always kept for all 9 footing models.

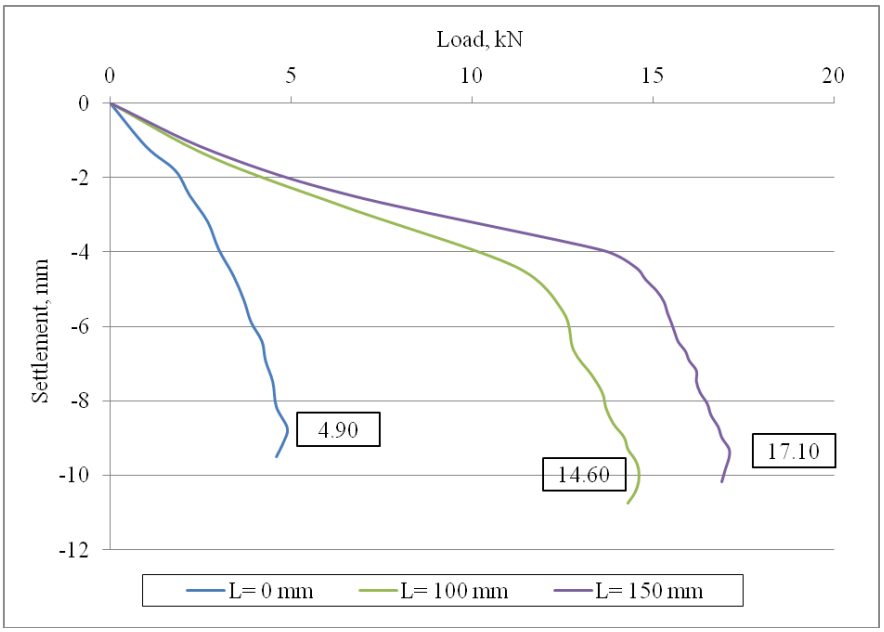

Figure 1Load-Settlemnet Relationship for Footing Diameter 75 mm

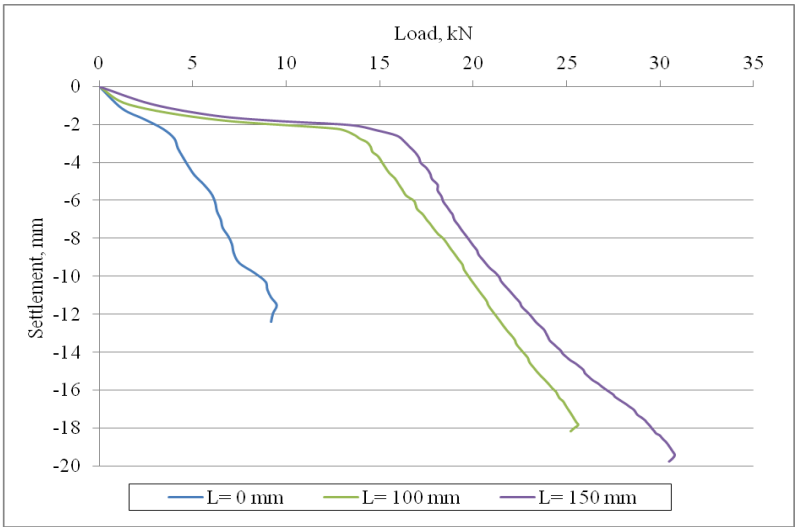

Figure 2Load-Settlement Relationship for Footing Diameter 100 mm

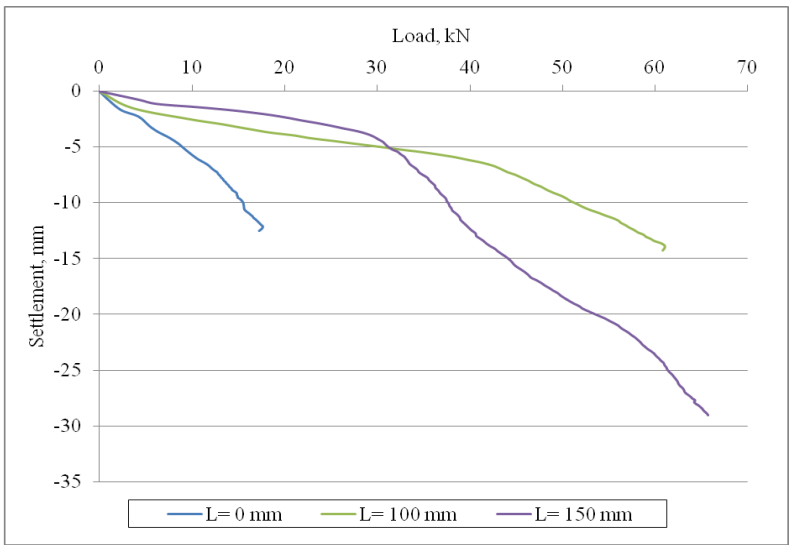

Figure 3Load-Settlement Relationship for Footing Diameter 150 mm

Seen from the figure 5 shows that the relationship between the load and settlement for all the curves are fairly linear for small-load range, and that the relationship are nonlinear for large-load ranges and its exhibit peak value, and can show also for footing model D=150 and L=150 haven't get the peak value that because the Hydraulic Loading Machine start going up and the footing model keep in same settlement. Then show the settlement increase when the load increase with appearing of deformation, soil failure can be observed after reaching the maximum load when the load starts to decrease.

3.1 Settlement in Similar Load as Reference

To know the value of the settlement caused by loading, the value of the settlement is taken at the same condition of load (P, kN) . The value of the load used as a reference is a load of 1.5 KN for all foundations is due to the settlement value of all samples through the load of 1.5 kN. The analysis of settlement in similar value of load 1.5 kN is shown on Figure 6-8

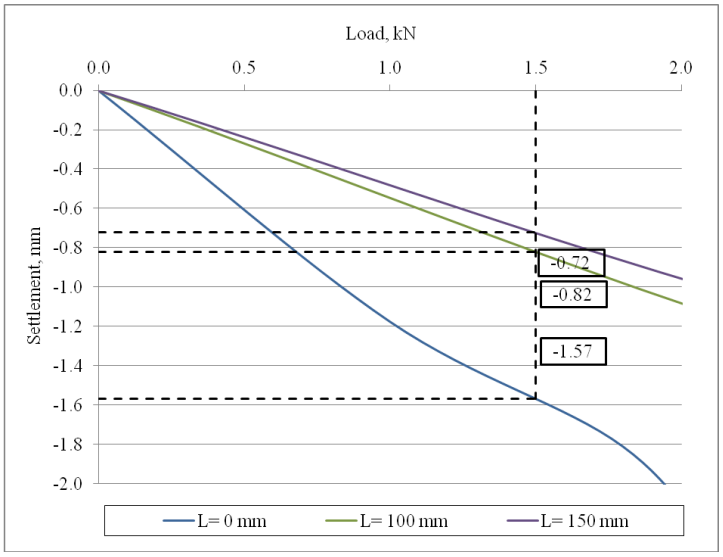

Figure 4Settlement Analysis on Footing Diameter 75 mm

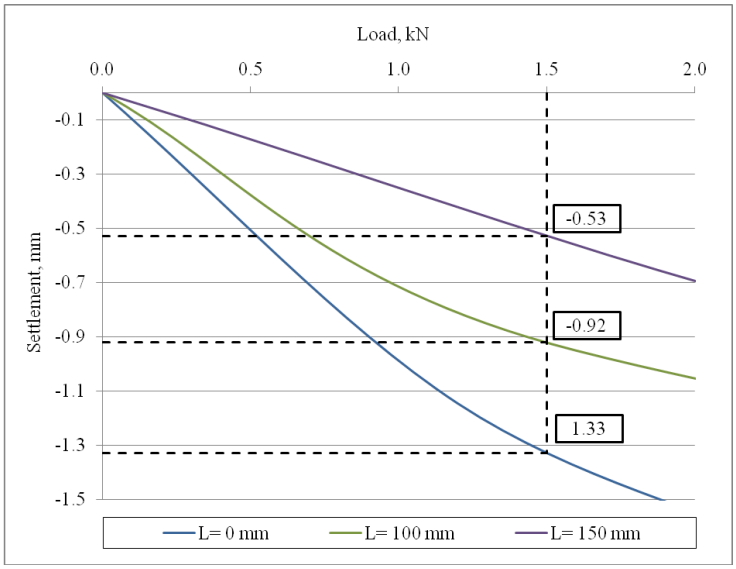

Figure 5Settlement Analysis on Footing Diameter 100 mm

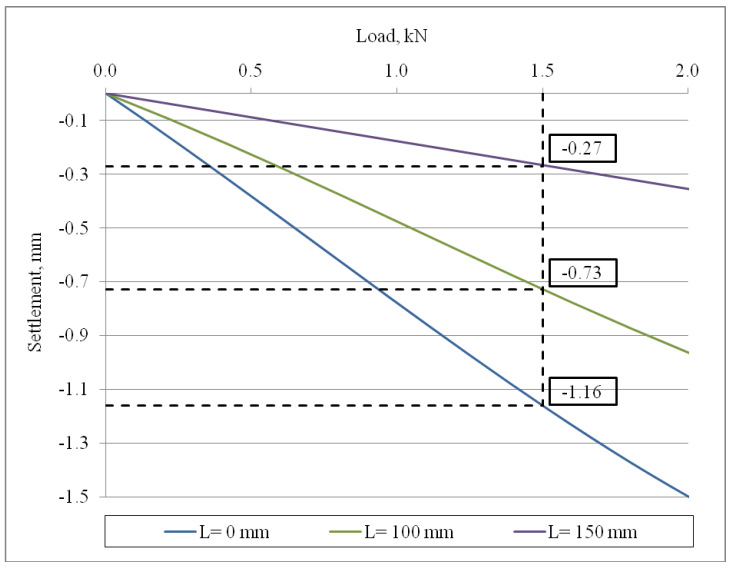

Figure 6 Settlement Analysis on Footing Diameter 150 mm

From figure 6-8 can be seen the value of the settlement at the same load that is 1.5 KN load. Then in Table V.1. Gives the result of the magnitude of the settlement caused by the length of the different skirt at the same diameter of the footing foundation.

Table 1 Settlement magnitude on load is 1.5 kN

Footing diameter D (mm)	Skirt length, L (mm)	L/D	Settlement (S) on 1.5 kN, (mm)
75	0	0.00	1.57
75	100	1.33	0.82
75	150	2.00	0.72
100	0	0.00	1.33
100	100	1.00	0.92
100	150	1.50	0.53
150	0	0.00	1.16
150	100	0.67	0.73
150	150	1.00	0.27

The table 1 also shows the different condition on L/D ratio, which is observed from the similar diameter and different skirt length, when the L/D ratio increased the settlement decreased. The magnitude of the settlement at 1.5 KN load caused by the length of the skirt indicates that as the length of the skirt lengthens, the value of the settlement becomes smaller.

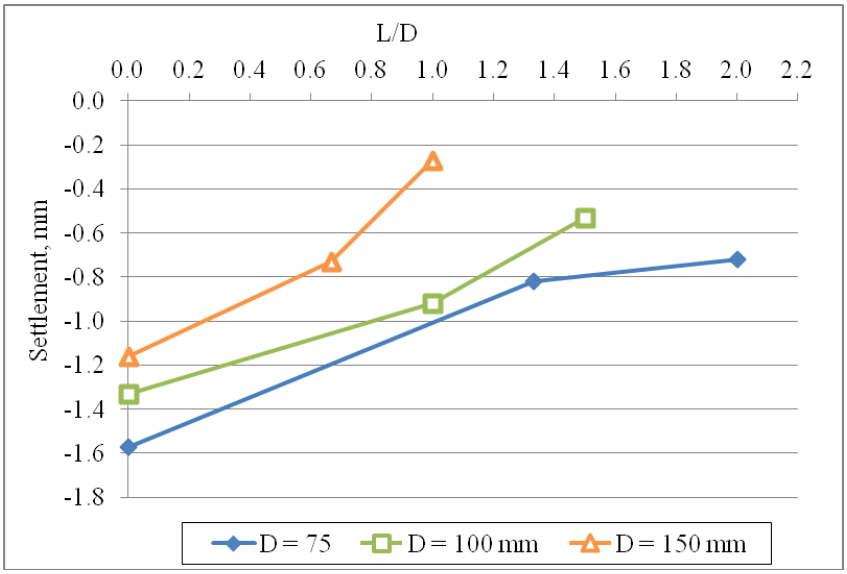

Figure 7L/D Ratio-Settlement Relationship, Different D

3.2 Load in Similar Settlement as Reference

To know the value of the load caused by the settlement, the load value is taken when the same settlement condition. The reference settlement of 3 mm for all foundations is due to the load value of all samples through a 3 mm settlement . Then, the figure shows that the load will increases when increases the length of skirt for all sample when same diameter.

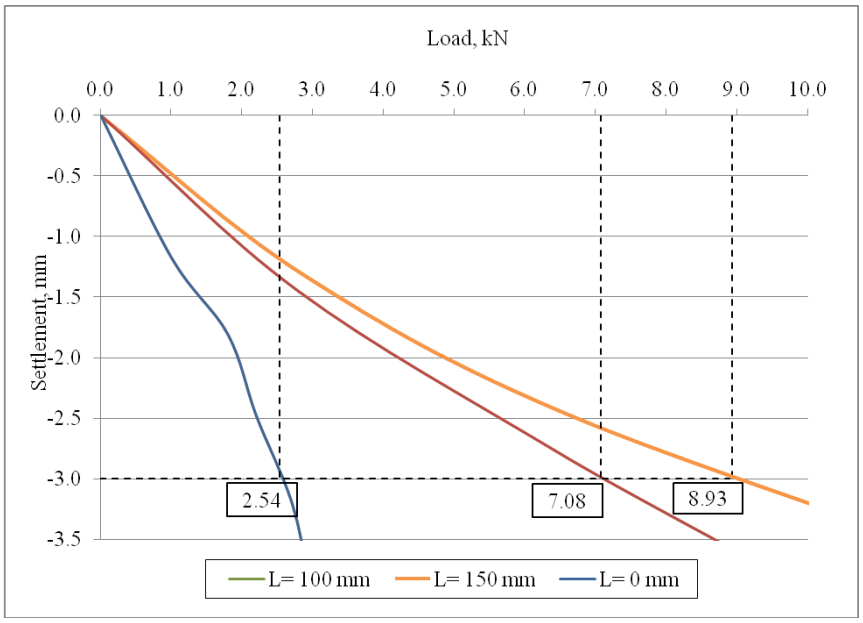

Figure 8Load in Similar Settlement on Footing Diameter 75 mm

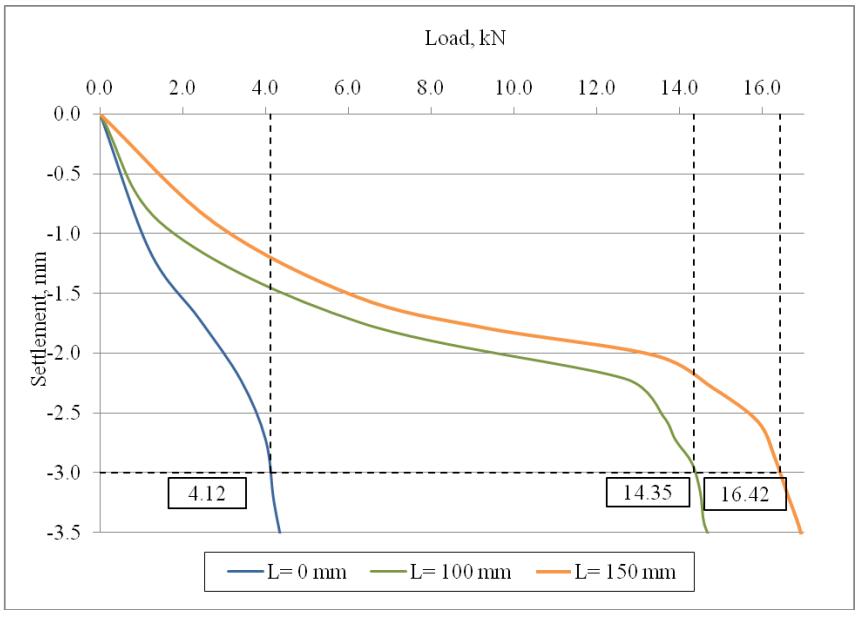

Figure 9Load in Similar Settlement on Footing Diameter 100 mm

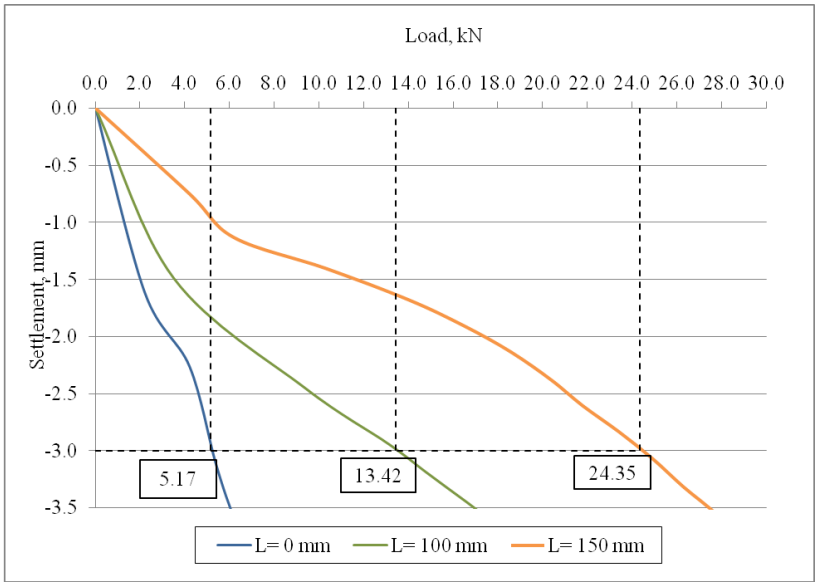

Figure 10Load in Similar Settlement on Footing Diameter 150 mm

Table 2 Load Magnitude in Similar Settlement on 3 mm

Footing diameter D (mm)	Skirt length, L (mm)	L/D	Area	Load (P) on 3 mm, (kN)
75	0	0.00	4419.64	2.54
75	100	1.33	4419.64	7.08
75	150	2.00	4419.64	8.93
100	0	0.00	7857.14	4.12
100	100	1.00	7857.14	14.35
100	150	1.50	7857.14	16.42
150	0	0.00	17678.57	5.17
150	100	0.67	17678.57	13.42
150	150	1.00	17678.57	24.35

It also happened on L/D ratio, which is observed on the similar diameter (D) and different length (L). The higher L/D ratio the greater the load generated.

3.3 Compare the Ultimate Bearing Capacity in the Maximum Load.

From figure 6-8 can be seen that the graph exhibit peak value for maximum load which the soil can carry without yielding or displacement is termed as the bearing capacity of soils. To compare the maximum bearing capacity can be support the footing without failure for all footing foundation, have to take the maximum load in all the footing with/without skirt it can be show when the load is decrease .

Table 3 Ult Bearing Capacity in Different Length and Diameter of Footing

Footing Diameter D (mm)	Area, A (mm^2)	Skirt Length, L (mm)	L/D	Max. Load, P_{max} (kN)	Ult. Bearing Capacity, q_u (kN/m^2)
75	4419.64	0	0.00	4.90	1108.69
75	4419.64	100	1.33	14.60	3303.43
75	4419.64	150	2.00	17.10	3869.09
100	7857.14	0	0.00	9.50	1209.09
100	7857.14	100	1.00	25.60	3258.18
100	7857.14	150	1.50	30.60	3894.55
150	17678.57	0	0.00	17.60	995.56
150	17678.57	100	0.67	61.00	3450.51
150	17678.57	150	1.00	65.70	3716.36

Form the Table 3 can seen that the Ult bearing capacity increase then increase the length of skirt footing. It can be seen with diameter (D) 75 mm with length (L) 0.00 mm = 1108.69 kN/m^2, (L) 100 mm = 3303.43 kN/m^2 and (L) 150 mm = 3869.09 KN/m^2. This shows that the longer the length of skirt footing, the greater the Ult bearing capacity.

3.4 Comparison the Value of Settlement on the same Load Condition Between Clay upper Sand Soils and sand upper Clay Soils.

With the existence of previous research data that is research of carrying capacity of skirted footing foundation on sand upper clay, can be compared with data of research result of carrying capacity of skirted footing foundation on clay upper sand. The foundation compared a number of nine simple in same condition of soil and water content. To get a comparable value of settlement, then taken the settlement when the same load is on the load 1 KN because all graph of clay upper sand and sand upper clay has reach the load 1 KN. From indicates that the footing foundation on the sand upper clay to lying down beneath the footing foundation on clay upper sand. For the value of settlement at 1 KN load, the value of degradation on sand upper clay soil is greater than clay upper sand soil. In this case it can be said that the clay upper sand has a greater carrying capacity compared to the sand upper clay. Example can be taken as the value of the settlement when the load of 1 KN on the foundation with D = 100 / L = 0 for the clay upper sand of 1.08 mm and sand 13.95 mm. In table 4 we can see the comparison result from clearer figure.

Table 4 The Value of the Comparison Between the Clay Upper Sand and Sand Upper Clay Soils.

Type of soil	Diameter Foundation D (mm)	Length of Skirted L (mm)	L/D	settlement (S) On 1 kN, (mm)
Clay Upper Sand	75	0	0,00	1.2
	75	100	1,33	0.5
	75	150	2,00	0.47
Sand Upper Clay	75	0	0,00	22.8
	75	100	1,33	13.3
	75	150	2,00	5.7
Clay Upper Sand	100	0	0,00	1.08
	100	100	1,00	0.71
	100	150	1,50	0.35
Sand Upper Clay	100	0	0,00	13.95
	100	100	1,00	1.73
	100	150	1,50	1.29
Clay Upper Sand	150	0	0,00	0.79
	150	100	0,67	0.48
	150	150	1,00	0.18
Sand Upper Clay	150	0	0,00	1.81
	150	100	0,67	1.56
	150	150	1,00	0,44

3.5 Comparison the Value of Load on the same Settlement Condition Between Clay upper Sand Soils and Sand upper Clay Soils.

With the existence of previous research data that is research of carrying capacity of skirted footing foundation on sand upper clay, can be compared with data of research result of carrying capacity of skirted footing foundation on clay upper sand. The foundation compared a number of nine simple in same condition of soil and water content. To get a comparable value of loading, then taken the load when the same settlement is on 3 mm because all graph of clay upper sand and sand upper clay has reach the settlement of 3 mm.

The comparing between skirted and unskirted footing foundation can show the shear failure of layered soils with and without skirt, and from the rustle can see that the bearing capacity is increase when increase the length of skirt that because the skirt attached to the periphery of the footing and extending to depth L confines the soil inside the skirt cell.

Therefore, the footing and the skirt cell with the soil inside are acting as one integrated system. As the length of skirt increases, the shallow footing is deeper seated, and the foundation depth increased. As a result of that, the ultimate bearing capacity of skirted footing increases as the length of skirt increased and the relative density of sand increased.

can seen the local shear failure of clay upper sand and sand upper clay on skirted footing , from figure can indicates that for clay upper sand the skirted footing have greater shear failure on sand and for sand upper clay the greater shear failure on clay. So in same footing diameter and length of skirted on clay upper sand have larger of maximum load and increase for settlement from sand upper clay, because the bearing capacity of sand bigger from bearing capacity of clay. In table 5 we can see the comparison result from clearer figure.

Table V.6. The Value of the Comparison Between the Clay Upper Sand and Sand Upper Clay Soils.

Type of soil	Diameter foundation D (mm)	Length of Skirted L (mm)	L/D	Load (L) on 3 mm, (KN)
Clay Upper Sand	75	0	0,00	2.58
	75	100	1,33	7.08
	75	150	2,00	8.93
Sand Upper Clay	75	0	0,00	0.36
	75	100	1,33	0.81
	75	150	2,00	0.97
Clay Upper Sand	100	0	0,00	4.11
	100	100	1,00	14.35
	100	150	1,50	16.42
Sand Upper Clay	100	0	0,00	0.69
	100	100	1,00	1.47
	100	150	1,50	1.6
Clay Upper Sand	150	0	0,00	5.2
	150	100	0,67	13.4
	150	150	1,00	24.35
Sand Upper Clay	150	0	0,00	1.47
	150	100	0,67	1.68
	150	150	1,00	1.96

4. CONCLUSIONS

From the accomplished laboratory tests, the following may be concluded:

The value of bearing capacity of clay upper sand for skirted and unskirted circular footing observed that at the same diameter of footing, the longer of skirt the higher of load and bearing capacity.

The magnitude of settlement for the influence of skirt length to footing diameter, L/D ratio observed on the similar diameter of footing with different length of skirt. It shown that the higher L/D ratio the smaller settlement.

The additional of skirt on the circular footing is effective to reduce the settlement on the clay upper sand. As can be seen when it is observed on the similar diameter footing and different length of skirt, the longer skirt the smaller settlement.

COURTESY

Because of the accomplishment of this final project, the author says thanks to:

Advisor of this final project, Mr. Anto Budi Listyawan, S.T., M.Sc., Yenny Nurchasanah, S.T, M. T., Mrs. Ir. Renaningsih, M.T., who have been taking the time to provide guidance and direction to completion of this final project.

My beloved all my family who always support me. Thanks for the better hope of me a long time, may Allah gives you all a best reward.

All my friends of Civil engineering, especially in International Program Class, thanks for your time as my partner.

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